THE AQUATIC PLANT COMMUNITY OF PEPPERMILL LAKE, ADAMS COUNTY, WISCONSIN

November 2006

Submitted by Reesa Evans,
Adams County Land & Water Conservation Department
P.O. Box 287, Friendship, WI 53934
608-339-4268

THE AQUATIC PLANT COMMUNITY FOR PEPPERMILL LAKE
ADAMS COUNTY 2006

I. INTRODUCTION

An updated aquatic macrophytes (plants) field study of Peppermill Lake was conducted during July 2006 by a staff member of the Wisconsin Department of Natural Resources and a staff member of the Adams County Land and Water Conservatism Department.

Information about the diversity, density and distribution of aquatic plants is an essential component in understanding the lake ecosystem due to the integral ecological role of aquatic vegetation in the lake and the ability of vegetation to impact water quality (Dennison et al, 1993). This study will provide information useful for effective management of Peppermill Lake, including fish habitat improvement, protection of sensitive areas, aquatic plant management, and water resource regulation. This baseline data will provide information that can be used for comparison to future information and offer insight into changes in the lake.

Ecological Role: Lake plant life is the beginning of the lake's food chain, the foundation for all other lake life. Aquatic plants and algae provide food and oxygen for fish and wildlife, as well as cover and food for the invertebrates that many aquatic organisms depend on. Plants provide habitat and protective cover for aquatic animals. They also improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake, and impact recreation.

Characterization of Water Quality: Aquatic plants can serve as indicators of water quality because of their sensitivity to water quality parameters such as clarity and nutrient levels (Dennison et al, 1993).

Peppermill Lake readings for hardness (average 198.5 mg/l of calcium carbonate) score its water as "very hard". The pH range has been between 6.09 and 7.97 in 2004-2006. Hard water lakes tend to produce more fish and aquatic plants than soft water lakes.

Background and History: Peppermill Lake is located in the Town of Jackson, Adams County, Wisconsin. The impoundment is 100 surface acres in size. Maximum depth is 14', with an average depth of about 6'. During the summer of 2006 when this aquatic plant survey was conducted, the lake was at slightly lower level than usual due to drought and very hot weather. There is a public boat ramp located on northeast end of the lake owned by the Town of Jackson. By the boat ramp is the Peppermill Dam, owned by Adams County, and managed by the Adams County Land & Water Conservatism Department.

Peppermill Lake is easily accessible off of County Highway G. Residential development around the lake is found along most of the lakeshore, except the northwest end, which is in conservancy. The surface watershed is 36.2% residential, 3.5% non-irrigated agriculture, 53.4% woodlands, and 2.58% water. The ground watershed, which extends north and west of the lake, contains 13.26% non-irrigated agriculture, 9.69% irrigated agriculture, 52.02% woodlands, 14.22% residential, 2.75% governmental (a federal prison), 0.48% open grassland, and 2.58% water. There are no known endangered or threatened aquatic and terrestrial resources in or directly around the lake. There are no identified archeological or historical sites in either the surface or ground watersheds.

Fish stocking records in the 1990s show that northern pike and largemouth bass were stocked by the Wisconsin Department of Natural Resources. Fish inventory in 1970 found that largemouth bass, bluegills, pumpkinseeds and white suckers were common, northern pike was present and rock bass was scarce. Through several other fish inventories, largemouth bass and bluegills tended to be abundant. A fish inventory in October 2006 revealed that the following fish were found in the lake (a full report is not yet available): northern pike; largemouth bass; bluegill; pumpkinseed; yellow perch; black crappie; bullhead; white sucker; and rock bass.

Soils directly around Peppermill Lake tend to be sand or loamy sand of less than 12% slope, except for some eroded silt loam with 12% to 29% slope at the far east end of the lake. Those in the surface and ground watersheds are also sands and loamy sands. Such soils tend to be excessively-drained, with infiltration of water being rapid to very rapid, and permeability also high. Such soils also usually have a low water-holding and low organic matter content, thus making them difficult to establish vegetation on. These soils tend to be easily eroded by both water and wind.

Efforts at controlling aquatic plant growth have included both chemical treatments and mechanical harvesting. 2006 figures are not yet available, but other information is shown below. Chemical treatment records go back to 1999. Chemicals used were specific to dicotyledons and were used to eliminate or control Eurasian Watermilfoil.

Year	Navigate	DMA-4 IVM
	(lbs)	(gal)
1999	300	
2000	700	
2001	1550	
2002	1400	
2003	352.23	5
2004	270	110
2005	300	
total	4872.23	115

Mechanical harvesting of aquatic plant started in 2003 and continued through 2006. The Lake District does not own a harvester, so hires a local contractor to perform the machine harvesting.

Year	Lbs Removed
2003	135,000
2004	114,000
2005	45,000
total	294,000

An aquatic plant survey using the transect & rake method was conducted by UWSP students in 2001. This survey found that the plant-like algae, *Chara spp*, had the highest frequency, followed by *Myriophyllum sibiricum, Najas flexilis*, and *Potamogeton zosterformis.* Found at lesser frequencies were *Ceratophyllum demersum, Elodea canadensis, Lemna minor, Myriophyllum spicatum, Nuphar advena, Nymphaea odorata, Potamogeton amplifolius, Potamogeton pectinatus, Potamogeton richardsonii, Scirpus validus, Spirodela polyrhiza, Typha latifolia, Utricularia spp. Chara spp*. was also the densest plant found. Of the 16 species found in 2001, two were emergent types, four were floating-leaf species, and ten were submergent species.

II. METHODS

Field Methods

The 2006 study was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random transects. The shoreline was divided into 19 equal sections, with one transect placed randomly within each segment, perpendicular to the shoreline.

One sampling site was randomly chosen in each depth zone (0-1.5'; 1.5'-5'; 5'-10'; 10'-20') along each transect. Using long-handled, steel thatching rakes, four rake samples were taken at each site. Samples were taken from each quarter around the boat. Aquatic species present on each rake were recorded and given a density rating of 0-5.

A rating of 1 indicates the species was present on 1 rake sample.

A rating of 2 indicates the species was present on 2 rake samples.

A rating of 3 indicates the species was present on 3 rake samples.

A rating of 4 indicates the species was present on 4 rake samples.

A rating of 5 indicates that the species was <u>abundantly</u> present on all rake samples.

A visual inspection and periodic samples were taken between transects to record the presence of any species that didn't occur at the raking sites. Gleason and Cronquist (1991) nomenclature was used in recording plants found.

Shoreline type was also recorded at each transect. Visual inspection was made of 50' to the right and left of the boat along the shoreline, 35' back from the shore (so total view was 100' x 35'). Percent of land use within this rectangle was visually estimated and recorded.

Data Analysis:

The percent frequency (number of sampling sites at which it occurred/total number of sampling sites) of each species was calculated. Relative frequency (number of species occurrences/total all species occurrences) was also figured. The mean density (sum of species' density rating/number of sampling sites) was calculated for each species. Relative density (sum of species' density/total plant density) was also figured. Mean density where present (sum of species' density rating/number of sampling sites at which species occurred) was calculated. Relative frequency and relative density results were summed to obtain a dominance value. Species diversity was measured by Simpson's Diversity Index.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated as outlined by Nichols (1998) to measure plant community disturbance. A coefficient of Conservatism is an assigned value between 0 and 10 that measures the probability that the species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients for the species found in the lake. The coefficient of conservatism is used to calculate the Floristic Quality Index, a measure of a plant community's closeness to an undisturbed condition.

An Aquatic Macrophyte Community Index was determined using the method developed by Nichols et al (2000). This measurement looks at the following seven parameters and assigns each of them a number on a scale of 1-10: maximum depth of plant growth; percentage of littoral zone vegetated; Simpson's diversity index; relative frequency of submersed species; relative frequency of sensitive species; taxa number; and relative frequency of exotic species. The average total for the North Central Hardwoods lakes and impoundments is between 48 and 57.

III. RESULTS

Physical Data

The aquatic plant community can be impacted by several physical parameters. Water quality, including nutrients, algae and clarity, influence the plant community; the plant community in turn can modify these boundaries. Lake morphology, sediment composition and shoreline use also affect the plant community.

The trophic state of a lake is a classification of water quality (see Table 1). Phosphorus concentration, chlorophyll a concentration and water clarity data are collected and combined to determine a trophic state. **Eutrophic lakes** are very productive, with high nutrient levels and a large biomass presence. **Oligotrophic lakes** are those low in nutrients with limited plant growth and small populations of fish. **Mesotrophic lakes** are those in between, i.e., those which have increased production over oligotrophic lakes, but less than eutrophic lakes; those with more biomass than oligotrophic lakes, but less than eutrophic lakes; those with a good and more varied fishery than either the eutrophic or oligotrophic lakes.

The limiting factor in most Wisconsin lakes, including Peppermill Lake, is phosphorus. Measuring the phosphorus in a lake system thus provides an indication of the nutrient level in a lake. Increased phosphorus in a lake will feed algal blooms and also may cause excess plant growth. **The 2004-2006 summer average phosphorus concentration in Peppermill Lake was 25.05 ug/l.** This is below the 65 mg/l average for impoundments. This concentration suggests that

Peppermill Lake is likely to have a few nuisance algal blooms, but not as frequently as many impoundments. This places Peppermill Lake in the “good” water quality section for impoundments, and in the “mesotrophic” level for phosphorus.

Chlorophyll concentrations provide a measurement of the amount of algae in a lake’s water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth. **The 2004-2006 summer average chlorophyll concentration in Peppermill Lake was 3.24 ug/l.** The low algae concentration places Peppermill Lake at the “oligotrophic” level for chlorophyll a results.

Water clarity is a critical factor for plants. If plants don’t get more than 2% of the surface illumination, they won’t survive. Water clarity can be reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color or cloud the water. Water clarity is measured with a Secchi disk. **Average summer Secchi disk clarity in Peppermill Lake in 2004-2006 was 8.91’.** This is very good water clarity, putting Peppermill Lake into the “oligotrophic” category for water clarity.

It is normal for all of these values to fluctuate during a growing season. They can be affected by human use of the lake, by summer temperature variations, by algae growth & turbidity, and by rain or wind events. Phosphorus tends to rise in early summer, than decline as late summer and fall progress. Chlorophyll a tends to rise in level as the water warms, then decline as autumn cools the water. Water clarity also tends to decrease as summer progresses, probably due to algae growth, then decline as fall approaches.

Table 1: Trophic States

Trophic State	Quality Index	Phosphorus (ug/l)	Chlorophyll a (ug/l)	Sechhi Disk (ft)
Oligotrophic	Excellent	<1	<1	>19
	Very Good	1 to 10	**1 to 5**	**8 to 19**
Mesotrophic	Good	**10 to 30**	5 to 10	6 to 8
	Fair	30 to 50	10 to 15	5 to 6
Eutrophic	Poor	50 to 150	15 to 30	3 to 4
Peppermill Lake		**25.05**	**3.24**	**8.91**

According to these results, Peppermill Lake scores as **“mesotrophic”** in its phosphorus level, and “**oligotrophi**c” in chlorophyll a readings, and Secchi disk readings. With such phosphorus readings and chlorophyll a readings, dense plant growth and frequent algal blooms would not be expected.

Lake morphology is an important factor in distribution of lake plants. Duarte & Kalff (1986) determined that the slope of a littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support higher plant growth than steep slopes (Engel 1985).

Peppermill Lake is a multi-lobed shallow impoundment. Most of the lake is very shallow, except for a few areas where marl was one mined. Those small holes are 11’ to 14’ deep. With very good water clarity and shallow depths, plant growth may be favored in Peppermill Lake, since the sun can get to most of the sediment to stimulate plant growth.

Sediment composition can also affect plant growth, especially those rooted. The richness or sterility and texture of the sediment will determine the type and abundance of macrophyte species that can survive in a particular area of the lake (see Table 2).

Table 2: Sediment Composition—Peppermill Lake

Sediment	Type	Zone 1	Zone 2	Zone 3	Overall
Hard	Sand	5.26%			1.85%
Mixed	Muck/Gravel	10.53%	5.26%		5.56%
	Sand/Silt	5.26%			1.85%
Soft	Marl/Muck	5.26%		6.25%	3.70%
	Marl/Peat		5.26%	6.25%	3.70%
	Marl/Silt		10.53%	12.50%	7.41%
	Muck	63.17%	47.37%	18.75%	44.45%
	Muck/Peat		5.26%		1.85%
	Peat		15.79%	50.00%	20.37%
	Silt	5.26%	10.53%		5.56%
	Silt/Muck	5.26%		6.25%	3.70%

Nearly 91% of the sediment in Peppermill Lake is soft with natural fertility and significant available water holding capacity. 100% of the sample sites were vegetated in Peppermill Lake, no matter what the sediment.

Shoreline land use often strongly impacts the aquatic plant community and thus the entire aquatic community. Impacts can be caused by increased erosion and sedimentation and higher run-off of nutrients, fertilizers and toxins applied to the land. Such impacts occur in both rural and residential settings.

Native shrub vegetation was the shoreline cover with highest percent cover (36.84%). But disturbed sites, such as those with traditional lawn, rock/riprap, hard structures and pavement, were also frequent, covering nearly 30% of the shoreline.

Table 3: Shoreland Land Use—Peppermill Lake

	Type	Frequency	Coverage
Vegetated	Herbaceous	100.00%	22.63%
Shoreline	Shrub	73.68%	36.84%
	Wooded	63.16%	15.26%
Disturbed	Bare soil	5.26%	0.26%
Shoreline	Cultivated Lawn	42.11%	20.79
	Hard Structure	36.84%	3.68%
	Pavement/Riprap	5.26%	0.53%

Some type of native vegetated shoreline was found 100% of the sites and covered 74.63% of the lake shoreline.

<u>Macrophyte Data</u>

SPECIES PRESENT

Of the 36 species found in Peppermill Lake, 35 were native and 1 was an exotic invasives. In the native plant category, 15 were emergent, 2 were free-floating plants, 3 were floating-leaf rooted, and 15 were submergent types (see Table 4). One exotic invasive, *Myriophyllum spicatum* (Eurasian Watermilfoil) was also found.

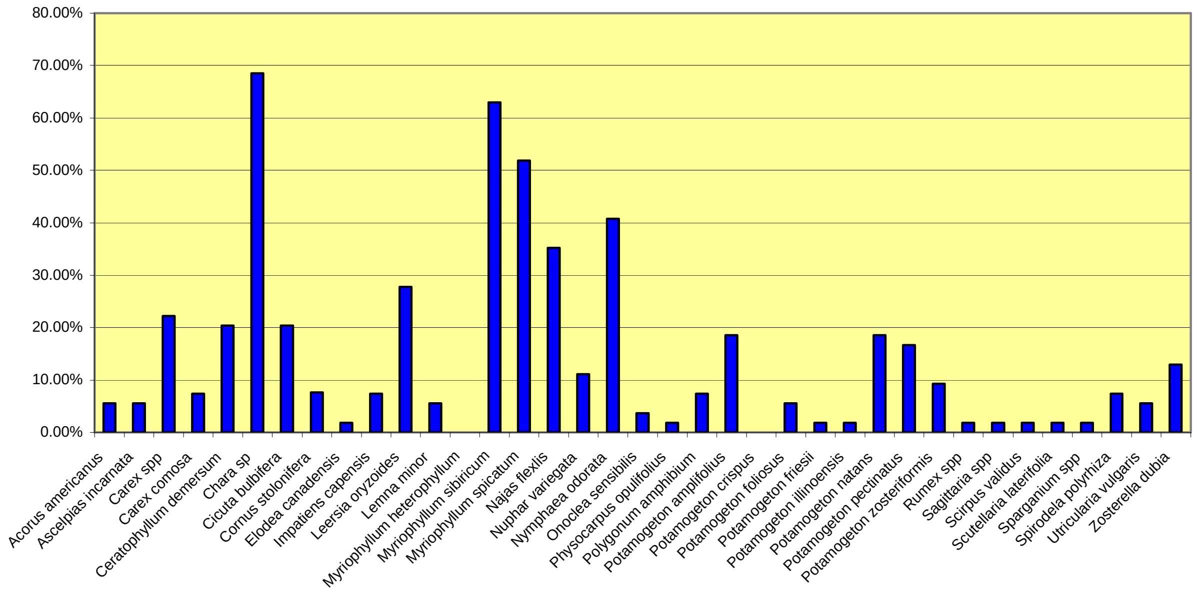
Table 4—Plants Found in Peppermill Lake, 2006

Scientific Name	Common Name	Type
Acorus americanus	Sweet Flag	Emergent
Ascelpias incarnata	Swamp Milkweed	Emergent
Carex spp	Sedge	Emergent
Carex comosa	Bottlebrush Sedge	Emergent
Ceratophyllum demersum	Coontail	Submergent
Chara sp	Muskgrass	Submergent
Cicuta bulbifera	Water Hemlock	Emergent
Cornus stolonifera	Red-Osier Dogwood	Emergent
Elodea canadensis	Waterweed	Submergent
Impatiens capensis	Jewelweed	Emergent
Leersia oryzoides	Rice Cut-Grass	Emergent
Lemna minor	Lesser Duckweed	Free-Floating
Myriophyllum heterophyllum	Variable-Leaf Milfoil	Submergent
Myriophyllum sibiricum	Northern Milfoil	Submergent
Myriophyllum spicatum	Eurasian Watermilfoil	Submergent
Najas flexlis	Bushy Pondweed	Submergent
Nuphar variegata	Yellow Pond Lily	Floating-Leaf
Nymphaea odorata	White Water Lily	Floating-Leaf
Onoclea sensibilis	Sensitive Fern	Emergent
Physocarpus opulifolius	Common Ninebark	Emergent
Polygonum amphibium	Water Smartweed	Floating-Leaf
Potamogeton amplifolius	Large-Leaf Pondweed	Submergent
Potamogeton crispus	Curly-Leaf Pondweed	Submergent
Potamogeton foliosus	Leafy Pondweed	Submergent
Potamogeton friesii	Fries' Pondweed	Submergent
Potamogeton illinoensis	Illinois Pondweed	Submergent
Potamogeton natans	Floating-Leaf Pondweed	Submergent
Potamogeton pectinatus	Sago Pondweed	Submergent
Potamogeton zosteriformis	Flat-Stem Pondweed	Submergent
Rumex spp	Water Dock	Emergent
Sagittaria spp	Arrowhead	Emergent
Scirpus validus	Soft-Stem Bulrush	Emergent
Scutellaria laterifolia	Scullcap	Emergent
Sparganium spp	Burreed	Emergent
Spirodela polyrhiza	Greater Duckweed	Free-Floating
Utricularia vulgaris	Common Bladderwort	Submergent
Zosterella dubia	Water Stargrass	Submergent

FREQUENCY OF OCCURRENCE

Chara spp and *Myriophyllum sibiricum* were the most frequently-occurring plants in Peppermill Lake in 2006 (with 68.52% and 62.96% frequency). The only other species that reached a frequency of 50% or greater was *Myriophyllum spicatum* (51.85%).

Chart 1: Occurrence Frequency

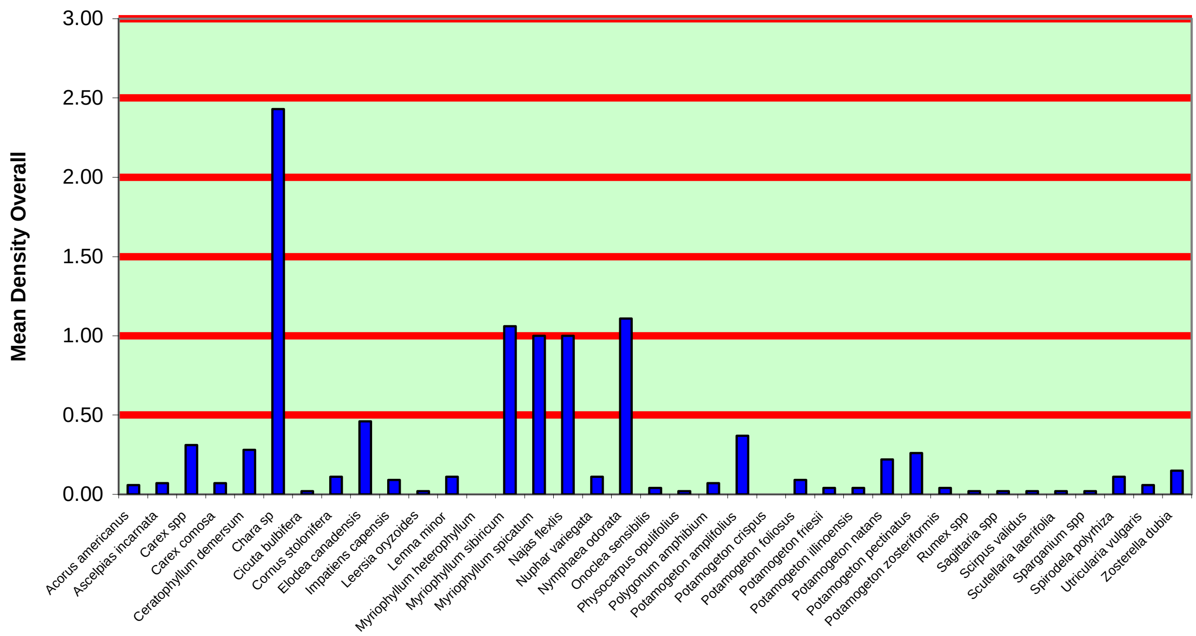


Filamentous algae was found at 48.15% of the sample sites.

DENSITY OF OCCURRENCE

Chara spp was the densest plant overall in Peppermill Lake, with a mean density of 2.43 (on scale of 1-5). This was the only species with more than average density of growth overall. It was the densest "plant" in Depth Zone 1 (0-1.5'), but did not have a more than average density in that zone, with a mean density of 1.26. However, in Depth Zone 2 (1.5'-5') and Depth Zone 3 (5'-10'), it did grow at more than average density, with densities of 2.74 and 3.25 respectively.

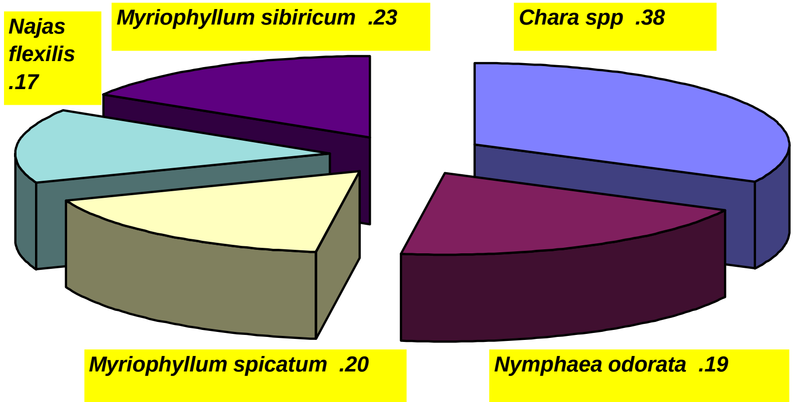
Chart 2: Occurrence Density



The above figures represent density of growth overall. However, if one looks at the "mean density where present", results are somewhat different. *Chara spp* is still the "plant" with the highest density where present, 3.54, but two other plants also have a more than average density where present: *Najas flexilis* (2.84) and *Nymphaea odorata* (2.73). This means these species exhibit a growth pattern of above average density, regardless of how frequently they occur in Peppermill Lake.

DOMINANCE

Relative frequency and relative density are combined into a dominance value that demonstrates how dominant a species is within its aquatic plant community. Based on dominance value, *Chara spp* was the dominant aquatic plant species in Peppermill Lake. There were no sub-dominant species. *Myriophyllum spicatum*, the most frequently-occurring exotic in Peppermill Lake, had a dominance of 0.20.



Nymphaea odorata was dominant in Depth Zone 1, with *Myriophyllum sibiricum* sub-dominant. *Chara spp* dominated Depth Zone 2, with *Myriophyllum sibiricum* sub-dominant. *Chara spp* was also dominant in Depth Zone 3, with *Myriophyllum spicatum* sub-dominant.

DISTRIBUTION

Aquatic plants occurred at 100% of the sample sites in Peppermill Lake to a maximum rooting depth of 7.5'. Free-floating plants were found in two depth zones; some filamentous algae were found in all three depth zones.

Secchi disc readings are used to predict maximum rooting depth for plants in a lake (Dunst, 1982). Based on the summer 2004-2006 Secchi disc readings, the predicted maximum rooting depth in Peppermill Lake would be **13.6 feet.** During the 2006 aquatic plant survey, rooted plants were found at a depth of **7.5’**, i.e., rooted plants were at a depth less to that to be expected by Dunst calculations. However, because the depths over 10’ are uncommon in Peppermill Lake and quite small in area, no rakes were taken in Depth Zone 4, so it is possible that plants grew in the deeper parts of the lake, but were not found in the transects.

The 0-1.5’ depth zone (Zone 1) produced the most frequently-occurring plant growth. There was a sharp drop in occurrence in Zone 2 (1.5’-5’), then another drop to Zone 3 (5’-10’). The same pattern was followed with aquatic plant density.

Chart 4: Zone Frequency

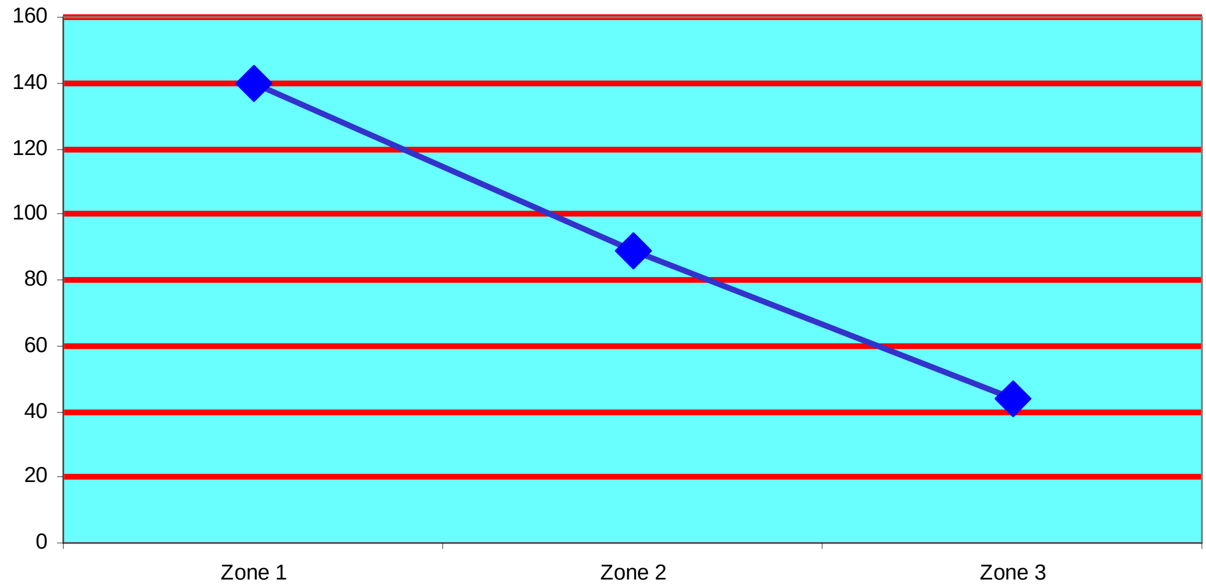
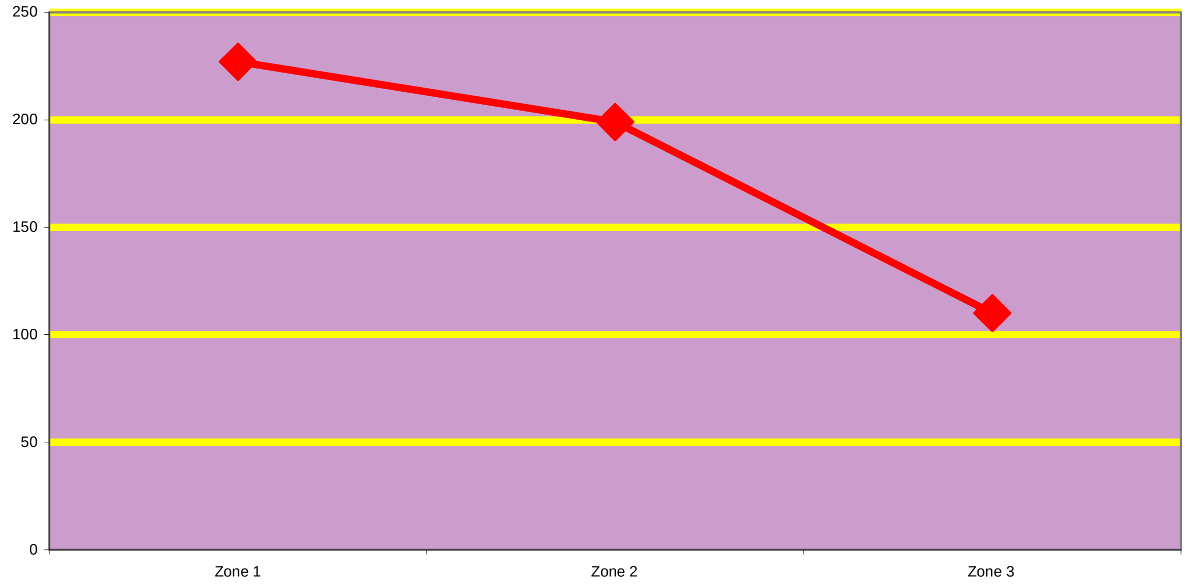


Chart 5: Zone Density



The greatest number of species per site (species richness) was found in Zone 1 with 6.17 species richness. A sharp drop was found in Zone 2 and Zone 3, with species richness of 4.63 and 3.33 respectively.

THE COMMUNITY

The Simpson's Diversity Index for Peppermill Lake was 0.93, an excellent species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). This places it in the upper quartile for Simpson's Diversity Index readings for both the North Central Hardwood Forest Region and all Wisconsin lakes. The AMCI for Peppermill Lake is 54, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes.

Table 5: Aquatic Macrophyte Community Index--2006

Aquatic Macrophyte Community Index for Peppermill Lake 2006		
Category	Peppermill Lake results	Value
Maximum rooting depth	7.5'	7
% littoral area vegetated	100%	10
%submersed plants	60%	6
% sensitive plants	6%	5
# taxa found	37 (3 exotic)	10
exotic species frequency	5%	6
Simpon's Diversity	.93	10
total		**54**

The presence of a highly invasive, exotic species like Eurasian Watermilfoil could be a significant factor in the future. Currently, EWM remains at high density and frequency, despite several years of chemical treatment and some mechanical harvesting. Its tenacity and ability to spread to large areas fairly quickly could make it an ongoing danger to the diversity, habitat value and equality of Peppermill Lake's aquatic plant community.

The Average Coefficient of Conservatism and a Floristic Quality Index calculation were performed on the field results. Technically, the Average Coefficient of Conservatism measures the community's sensitivity to disturbance, while the Floristic Quality Index measures the community's closeness to an undisturbed condition. Indirectly, they measure past and/or current disturbance to the particular community.

Previously, a value was assigned to all plants known in Wisconsin to categorize their probability of occurring in an undisturbed habitat. This value is called the plant's Coefficient of Conservatism. A score of 0 indicates a native or alien opportunistic invasive plant. Plants with a value of 1 to 3 are widespread native plants. Values of 4 to 6 describe native plants found most commonly in early successional ecosystem. Plants scoring 6 to 8 are native plants found in stable climax conditions. Finally, plants with a value of 9 or 10 are native plants found in areas of high quality and are often rare, endangered or threatened. In other words, the lower the numerical value a plant has, the more likely it is to be found in disturbed areas.

The Average Coefficient of Conservatism in Peppermill Lake in 2006 was 5.00. This makes it below average for Wisconsin Lakes (average 6.0) and for lakes in the North Central Hardwood Region average (average 5.6). The aquatic plant community in Peppermill Lake is in the category of those closer to disturbance and more tolerant of disturbance than the average lake in the North Central Hardwood Region and Wisconsin Lakes overall.

The Floristic Quality Index of the aquatic plant community in Peppermill Lake of 28.28 is above average for Wisconsin Lakes (average 22.2) and the North Central Hardwood Region (average 20.9). This suggests that the plant community in Peppermill Lake is closer to an undisturbed condition than the average lake in Wisconsin overall and in the North Central Hardwood Region.

“Disturbance” is a term that covers many disruptions to a natural community. It includes physical disturbances to plant beds such as boat traffic, plant harvesting, chemical treatments, dock and other structure placements, shoreline development and fluctuating water levels. Indirect disturbances like sedimentation, erosion, increased algal growth, and other water quality impacts will also negatively affect an aquatic plant community. Biological disturbances such as the introduction of non-native and/or invasive species (such as the Eurasian Watermilfoil found here), and destruction of plant beds by aquatic wildlife can also negatively impact an aquatic plant community. Shore development and sediment deposition can also reduce the quality of the aquatic plant community.

Some of the sample transects had an entirely native shore, although more sites had some disturbance by humans. Transect data was divided between natural and disturbed shores transects, then calculated as two separate lakes. This allowed a comparison of the two shore types on several criteria.

	Natural	**Disturbed**
Number of species	30	27
FQI	53.31	50.81
Average Coef. Of Cons	9.73	9.78
Simpson's Index	0.93	0.89
AMCI	49	47
Filamentous algae	51.85%	81.48%

Using these figures, the natural shores community supported more aquatic species, had a higher score for FQI, a higher Simpson’s Diversity Index, and a higher Aquatic Macrophyte Community Index, as well as less filamentous algae. These results suggest that natural shores may have higher quality habitat and water quality than disturbed shores.

IV. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Peppermill Lake is a mesotrophic impoundment with very good water clarity and good to very good water quality. This trophic state should support moderate plant growth and occasional algal blooms.

Sufficient nutrients (trophic state), very good water clarity, shallow lake, and soft sediments at Peppermill Lake favor plant growth. 100% of the lake is vegetated, suggesting that even the sand sediments in Peppermill Lake hold sufficient nutrients to maintain aquatic plant growth.

Historically, most aquatic plant treatments in Peppermill Lake were chemical. There has recently been mechanical harvesting to try to reduce plant growth. A continued regular schedule and pattern of machine harvesting could help in removing vegetation from the lake and may somewhat help with nutrient reduction. The harvesting should also follow the schedule in the management plan to target Eurasian Watermilfoil growth. Care should be taken not to spread it further.

The lake does have a mixture of emergent, free-floating, floating-leaf and submerged plants. Of the 37 specific species found in Peppermill Lake, 35 were native and 2 were exotic invasives. In the native plant category, 15 were emergent, 2 were free-floating plants, 3 were rooted floating-leaf plants, and 15were submergent types. Two exotic invasives, *Myriophyllum spicatum* (Eurasian Watermilfoil) and *Potomogeton crispus* (Curly-Leaf Pondweed), werefound.

Chara spp and *Myriophyllum sibiricum* were the most frequently-occurring plants in Peppermill Lake in 2006 (with 68.52% and 62.96% frequency). The only other species that reached a frequency of 50% or greater was *Myriophyllum spicatum* (51.85%).

Chara spp was the densest "plant" overall in Peppermill Lake, with a mean density of 2.43. This was the only species with more than average density of growth overall. It was the densest "plant" in Depth Zone 1 (0-1.5'), but did not have a more than average density in that zone, with a mean density of only 1.26.

However, in Depth Zone 2 (1.5'-5') and Depth Zone 3 (5'-10'), it did grow at more than average density, with densities of 2.74 and 3.25 respectively.

The Simpson's Diversity Index Peppermill Lake was 0.93, indicating very good species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). This places it in the upper quartile for species diversity for both North Central Hardwood Forest and all Wisconsin lakes. The AMCI for Peppermill Lake is 53, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes.

Some kind of native vegetation was the dominant shore cover in Peppermill Lake (total of 74.63%). However, disturbed sites, such as those with bare soil, cultivated lawn, hard structure, rock/riprap and pavement, were also common, with coverage of 25%. Shrub vegetation had the most coverage (36.84%). Some type of disturbed shoreline was found at 47.37% of the sites. These conditions result in reduced habitat value and reduced protection for water quality and have potential to negatively impact Peppermill Lake's water quality by increased runoff (including lawn fertilizers, pet waste, pesticides) and shore erosion.

The buffers of wooded, herbaceous, shrub and wetland shores on the much of the shore of the lake should be maintained as they are to preserve habitat and to serve as a buffer for water quality. Studies have suggested that runoff from established native vegetated land is substantially less than that of developed areas. There are also some areas of deep erosion on steep banks that need to be addressed to prevent tree fall (and related root ball removal from bank) and preserve the bank.

An aquatic plant community evaluation was conducted on Peppermill Lake in 2001, but using different depth zones and different transects. Thus, comparing the results of the 2001 survey and 2006 survey has to be done with caution. However, the 2001 surveyors did calculate Coefficient of Conservatism, Floristic Quality Index, Simpson's Index of Diversity and the AMCI

	2001	2006
Number of Species	17	32
Aver. Coef. Of Cons	4.76	5.00
FQI	19.65	28.28
Simpson's Index	0.90	0.93
AMCI	43	54

All the measures discussed in this report used to determine the quality of an aquatic plant community were higher in 2006 than in 2001. *Chara* spp ws the most frequently-occurring species in both 2001 and 2006, with *Myriophyllum spicatum* quite frequent in both years. It is likely that the high frequency of *Chara* spp assists in keeping the *Myriophyllum spicatum* less frequent. It appears that the efforts the Lake District is making to improve and/or maintain its lake water health are effective.

A reliable coefficient of similarity calculation between the 2001 and 2006 surveys can't be done because of the difference in methods of aquatic plant survey used. However, it is worth noting that the 2001 survey revealed only 2 emergent plants, while the 2006 survey resulted in 15 emergent plants being found. The 2006 aquatic plant community appears to be gaining a more varied structure than was present during the 2001 survey.

V. CONCLUSIONS

Peppermill Lake is a mesotrophic to oligotrophic impoundment with good water quality and good to very good water clarity. The Average Coefficient of Conservatism and FQI for Peppermill Lake indicate that it is more disturbance-tolerant and farther from an undisturbed condition than the average Wisconsin lake and North Central Hardwood region lake. The AMCI is in the average range for both North Central Hardwood Region and all Wisconsin lakes. This is likely due to an above average amount of disturbance to the lake. Filamentous algae were abundant. Structurally, the aquatic plant community contains emergent plants, free-floating plants, floating-leaf rooted plants and submergent plants.

When the aquatic plant survey was performed in 2006, 100% of the littoral zone was vegetated. Because of the shallow depths and very good water clarity, the potential for plant growth at all depths of the lake is present, even though a few of the lake sediments are sandy. This percent of plant cover is slightly over the recommended plant cover for a balanced fishery (50%-85%).

Chara spp and *Myriophyllum sibiricum* were the most frequently-occurring plant in Peppermill Lake in 2006 (with 68.52% and 62.96% frequency). The only other species that reached a frequency of 50% or greater was *Myriophyllum spicatum* (51.85%). *Chara spp* was the densest species overall in Peppermill Lake, with a mean density of 2.43. This was the only species with more than average density of growth overall.

A healthy and diverse aquatic plant community plays a vital role within the lake ecosystem. Plants help improve water quality by trapping nutrients, debris and pollutants in the water body; by absorbing and/or breaking down some pollutants;

by reducing shore erosion by damping wave action and stabilizing shorelines and lake bottoms; and by tying-up nutrients that would otherwise be available for algae blooms. Aquatic plants provide valuable habitat resources for fish and wildlife, often being the base level for the multi-level food chain in the lake ecosystem, and also produce oxygen needed by aquatic animals.

Further, a healthy and diverse aquatic plant community can better resist the invasion of species (native and non-native) that might otherwise "take over" and create a lower quality aquatic plant community. A well-established and diverse plant community of natives can help check the growth of more tolerant (and less desirable) plants that would otherwise crowd out some of the more sensitive species, thus reducing diversity.

Vegetated lake bottoms support larger and more diverse invertebrate populations that in turn support larger and more diverse fish and wildlife populations (Engel, 1985). Also, a mixed stand of aquatic macrophytes (plants) supports 3 to 8 times more invertebrates and fish than do monocultural stands (Engel, 1990). A diverse plant community creates more microhabitats for the preferences of more species.

MANAGEMENT RECOMMENDATIONS

(1) Because the plant cover in the littoral zone of Peppermill Lake is over the ideal (25%-85%) coverage for balanced fishery, the District should continue harvesting plan to reduce cover and open areas for fish. Dense vegetation removal by hand in shallow water can be removed to a maximum 30' channel out of 100' of shoreline at each property.

(2) Natural shoreline restoration and erosion control in some areas are needed. Biological shoreline restoration is preferred. If trees fall due to continued erosion, large portions of the banks will fall with them. The areas where there

is undisturbed vegetated shore should be maintained and left undisturbed for water quality & habitat protection.

(3) To protect water quality, a buffer area of native plants should be restored on those sites that now have traditional lawns mowed to the water's edge. This is especially important because more than ¼ of the shoreline is currently impacted by disturbed shores.

(4) Buffers already installed around the lake should be maintained in their current condition.

(5) Stormwater management on the impervious surfaces around the lake is essential to maintain the high quality of the lake water. For example, County G runs near one edge of the lake, resulting in runoff from the pavement into the lake.

(6) No lawn chemicals should be used on properties around the lake. If they must be used, they should be used no closer than 50' to the shore.

(7) Septic systems around the lake should be regularly inspected and maintained properly.

(8) The integrated aquatic plant management plan within the Lake Management Plan should be followed. This plan includes mechanical harvesting and chemical spot treatment. The plan should include target harvesting for Eurasian Watermilfoil (EWM) to prevent further spread, as well as avoiding sensitive areas and beds of lily pads.

(9) The Peppermill Lake District may want to apply for grants from the Wisconsin Department of Natural Resources to help defray the cost of aquatic plant management.

(10) No broad-scale chemical treatments of aquatic plant growth are recommended due to the undesirable side-effects of such treatments, including increased nutrients from decaying plant material and decreased dissolved oxygen and opening up more areas to the invasion of EWM.

(11) Peppermill Lake has long participated in the Self-Help Monitoring Program through the WDNR. Continued participation is recommended.

(12) Peppermill Lake residents should identify, cooperate with and participate in watershed programs that will reduce nutrient and sediment inputs.

(12) Critical habitat areas were formally determined in 2006, with a report due out later this year. The lake management plan should include recommendations for preserving these areas in its update.

(13) The Peppermill Lake District should make sure that its lake management plan takes into account all inputs from both the surface and ground watersheds and addresses the concerns of this lake community.

(14) Cooperation with the Town of Jackson in keeping the boat ramp in safe condition should help reduce any negative impacts caused by the heavy use of this public area.

LITERATURE CITED

Dennison, W., R. Orth, K. Moore, J. Stevenson, V. Carter, S. Kollar, P. Bergstrom and R. Batuik. 1993. Assessing water quality with submersed vegetation. BioScience 43(2):86-94.

Duarte, Carlos M. and Jacob Kalff. 1986. Littoral slope as a predictor of the maximum biomass of submerged macrophyte communities. Limnol.Oceanogr. 31(5):1072-1080.

Dunst, R.C. 1982. Sediment problems and lake restoration in Wisconsin. Environmental International 7:87-92.

Engel, Sandy. 1985. Aquatic community interactions of submerged macrophytes. Wisconsin Department of Natural Resources, Technical Bulletin #156. Madison, WI.

Gleason, H, and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada (2nd Edition). New York Botanical Gardens, N.Y.

Jessen, Robert, and Richard Lound. 1962. An evaluation of a survey technique for submerged aquatic plants. Minnesota Department of Conservatism. Game Investigational Report No. 6.

Nichols, Stanley. 1998. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2):133-141.

Nichols, S., S. Weber and B. Shaw. 2000. A proposed aquatic plant community biotic index for Wisconsin lakes. Environmental Management 26(5):491-502.

Shaw, B., C. Mechenich and L. Klessig. 1993. Understanding Lake Data. University of Wisconsin-Extension. Madison, WI.